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3,145,071

HIGH SPEED THERMAL CONTACT PRINTER

Filed Sept. 11, 1961

2 Sheets-Sheet 1

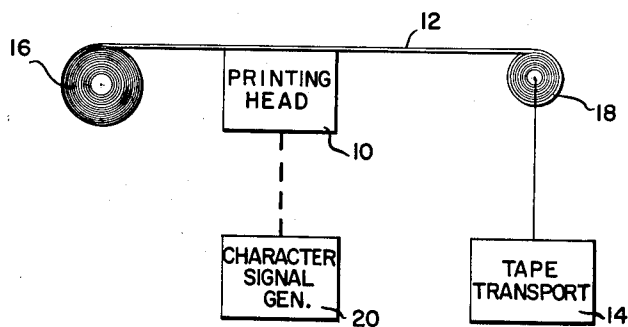


Fig. 1.

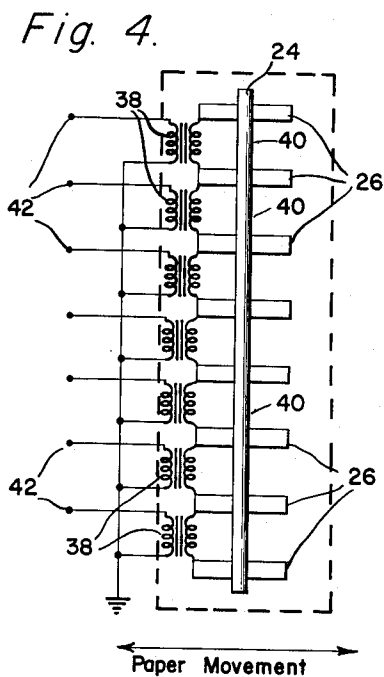


Fig. 2.

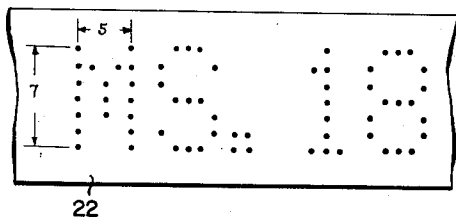
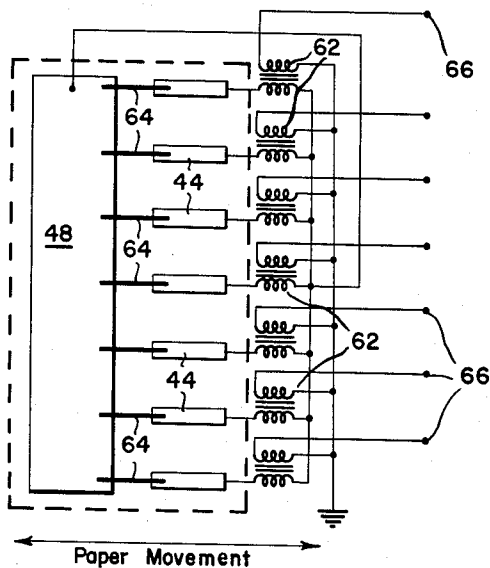


Fig. 6.



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Fig. 3.

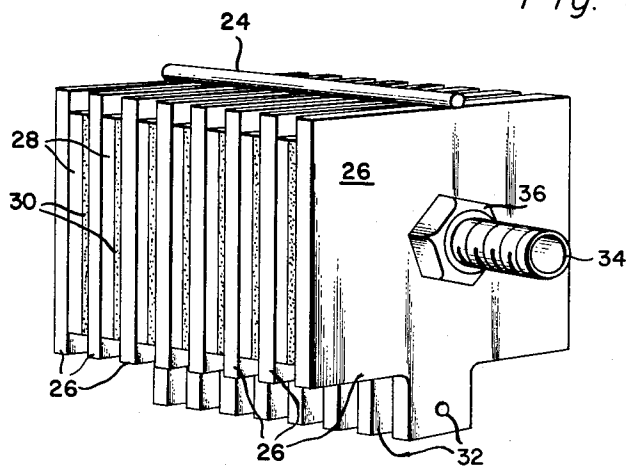
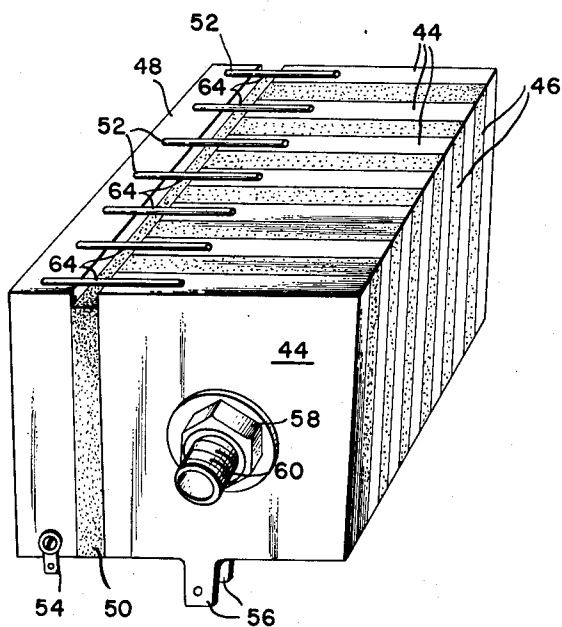


Fig. 5.



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## HIGH SPEED THERMAL CONTACT PRINTER

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6 Claims. (Cl. 346-76)

This invention relates to printing devices and more particularly to a high speed thermal contact printing element.

Printing devices, particularly when designed for use with modern high speed electronic data transmission and storage devices, present a relatively difficult problem in that they must operate at speeds far in excess of those available with prior art devices, and in that they must provide reliability of a high order. Many printing elements have been adapted for such use operating on many different principles. A printing technique having many useful features has been used for some time for the reproduction of documents and other records. This technique is based upon the use of a heat sensitive paper which responds by local darkening to the presence of a heat source. Reproduction devices utilizing such sensitive paper have been developed and have been in commercial use for some time. However, the speed of response of such devices has been relatively low and existing devices achieve relatively low reproduction rates.

The reason for the relatively low reproduction rates has been that in prior art devices, heat is applied to the heat sensitive paper by a radiation technique, which is an inherently slow method of heat transfer. Thus it has not been possible heretofore to produce a practical high speed printing device using commercially available heat sensitive paper.

It is therefore an object of the present invention to provide a thermal printing element which is responsive to relatively large changes in temperature at an extremely rapid rate.

It is a further object of this invention to provide a high speed printing device which transfers heat to commercially available heat sensitive paper by heat conduction.

It is a still further object of this invention to provide a reliable inexpensive printing device, which is used in conjunction with electronic data transmission and storage systems.

Briefly described, the present invention comprises a novel high speed printing element which is maintained in contact with heat sensitive paper and which can be actuated by a punched paper tape or other device containing stored information.

Further and additional objects and advantages of the present invention may be understood by reference to the following specification and drawings in which:

FIG. 1 shows a schematic diagram of a device embodying the present invention.

FIG. 2 shows a portion of the heat sensitive paper tape forming a part of the present invention.

FIG. 3 is a perspective view of an embodiment of a heating element constructed according to the principles of the present invention.

FIG. 4 is an electrical schematic diagram of the present invention using the heating element of FIG. 3.

FIG. 5 is a perspective view of a second embodiment of a heating element.

FIG. 6 is an electrical schematic diagram of the present invention using the heating element of FIG. 5.

A complete understanding of the heating element forming a part of the present invention requires the consideration of some basic physical laws. It should first be understood that the printing element will mark the sensitized paper by a heat transfer which will be almost ex-

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clusively heat conduction. When heat conduction is considered, the dynamic heat response characteristic of a material is best described by its diffusivity constant, which is equal to the ratio of the thermal conductivity of the material to the heat capacity per unit volume of the material. As an example, the diffusivity of silver is known to be approximately  $1.7 \text{ cm}^2/\text{sec}$ .

The printing element described in connection with the present invention uses very short heat conducting elements of extremely small cross section between relatively massive heat sinks. This structure achieves rapid cooling and also limits the application of high temperatures to those areas where marking of the sensitized paper is desired. In addition, the conducting elements must have suitable high diffusivity, if the extremely rapid heating and cooling of the conducting elements is to be achieved. In operation, it is also necessary to supply power densities to the conductors of a magnitude not previously considered in thermal marking devices. For example, if an element of silver must be heated and cooled by  $200^\circ \text{C}$ . in a time of the order of one millisecond, approximately 33.4 watts must be supplied to the conductor, assuming that the conductor is a wire of length approximately  $8.0 \times 10^{-2} \text{ cm}$ . and of cross section approximately  $4.0 \times 10^{-2} \text{ cm}^2$ .

In order to provide such power to the conductor, approximately 640 amperes must be supplied thereto. It may be desirable to supply current to the conducting elements in pulses of relatively short duration. Such operation has the further advantage that the time during which the conducting elements must remain at high temperature is reduced and hence conduction losses for the conducting elements are correspondingly reduced. It has been found experimentally that power and current densities may be used which are one or two orders of magnitude greater than those given above.

The use of the printing element described herein provides a practical method of high speed thermal paper marking. Using the present invention, numeric or alphanumeric data printers, of the "matrix" type in which characters are formed from a field of dots may be provided. The printing element taught by the present invention can yield reproducing devices operating at speeds up to approximately ten pages per minute. The printing element may be used to record information presented in the form of punched holes or mechanical, printed or xerographic marks on tapes or cards, and may be adapted to receive information from other input devices as well.

Turning now to FIG. 1, a high speed thermal contact printing element 10 is shown. The details of construction and operation of the printing element or head 10 will be described below. A heat sensitive paper tape 12 is maintained in contact with the printing head 10 while it is being moved across the surface of the printing head 10 by a tape transport mechanism 14. The transport mechanism 14 includes a pair of reels 16 and 18 adapted to receive and store the tape 12. A character signal generator 20 provides electrical signals to the printing head 10. The exact nature of the character signal generator 20 will depend upon the source of the character signals which may be a magnetically recorded tape, a punched paper tape, or other desirable input sources. In any event, the character signal generator 20 must provide signals to the printing head 10 which will produce a desired tape format. One such tape format is shown in FIG. 2.

In FIG. 2, characters are shown on a tape 22 in the form of a plurality of dots or local darkenings of the tape surface. While the printing element may be used to produce other formats, in the format shown, the maximum height of a character is given as seven dots and the maximum width of a character is given as five dots. Such a

format has been shown to yield extremely legible results when used with the printing element described in the present invention.

Generally, if a single line of printing is desired, as shown in FIG. 2, an entire vertical line, comprising up to seven dots, is printed simultaneously. As the tape 22 advances, the characters are printed in sequence, each character appearing as a succession of vertical lines of dots. The paper tape, obviously, must travel in a horizontal direction with respect to FIG. 2. However, the printing element forming the subject of the present invention may be used to form a character by printing a succession of horizontal lines of dots. Such character formation would be useful, for example, when it is desired to use a plurality of printing elements, operating simultaneously to produce an entire line of characters. In this case, paper travel must be in a vertical direction with respect to FIG. 2.

If a paper tape, which is punched with holes in accordance with the tape format described above, is used in connection with the present invention, the character signal generator may be an extremely simple device. In this case, it is merely necessary to establish a one to one correspondence between the holes in the punched paper tape and the input leads to the printing head. Thus the existence of a hole on the punched paper tape must yield an electrical signal at the input of one of the printing elements comprising the printing head 10. Tape readers well known in the prior art provides such electrical signals. These signals can be used to actuate the printing head 10 as will be shown hereinafter.

It has been found that the geometrical aspects of design of the printing head of the thermal contact printer are critical if necessary and sufficient electrical and heat conduction paths are to be obtained. The present invention shows two embodiments which yield suitable electrical and heat conduction paths. The first embodiment, shown in FIGS. 3 and 4, provides a thermal series circuit in which the printing elements are serially connected with respect to the heat conduction arrangement. The second embodiment, shown in FIGS. 5 and 6, shows a printing head in which the printing elements are connected in parallel.

Referring now to FIG. 3, the series connected printing head uses a long wire or bar 24, which may be soldered, brazed or welded to the edges of a plurality of metal plates 26. The bar 24 and the metal plates 26 may be composed of materials such as silver, copper or aluminum which exhibit a relatively high thermal and electrical conductivity. The metal plates 26 are perpendicularly disposed with respect to the wire or bar 24. A plurality of spacing plates 28 of a material having similar characteristics to that of the bar 24 and the connector plates 26 are interleaved with the connector plates 26 and provide additional thermal and electrical conduction paths. Each pair of connector plates 26 and spacing plates 28 is electrically isolated from an adjacent pair of plates by a plate of insulating material 30 which is made as thin as practical. Mica has been found to be a suitable insulating material. However, it is also possible to oxidize, anodize, or otherwise chemically treat the metal plates themselves so as to provide sufficient electrical insulation. Each of the connector plates 26 is provided with an electrical connection tab 32 for convenience in making external connections to the connector plate. Assembly and alignment of the printing head is provided by a bolt 34 and a tightening nut 36. The bolt 34 fits into a hole journalled through the assembly of connector plates 26, spacing plates 28, and insulating plates 30 and must be insulated from the connector plates 26 and the spacer plates 28. In addition, the bolt 34 may be made hollow so that air or liquid coolant may be passed therethrough to assist cooling of the printing elements if necessary.

In the device of FIG. 3, the heat sensitive tape is moved in a direction perpendicular to the direction of the bar

24. In order to provide a smooth contact surface between the printing head and the heat sensitive tape, the connector plates 26 may be made curved instead of flat as shown in FIG. 3 and the wire or bar 24 may be recessed into the plates 26. The space between plates 26 may be filled with insulating material to further assist in providing the smooth surface. If it is found necessary, a soft roller may be used to press heat sensitive tape into intimate contact with the printing head.

Referring to FIG. 4, the necessary electrical connections to the printing head shown in FIG. 3 are shown. A plurality of transformers 38, each having its secondary winding connected between a pair of adjacent connector plates, provides the electric current necessary for heating a printing element 40. The primary windings of the transformers 38 may be excited by amplifiers, power gates, relays, etc. These primary windings are selectively excited under the control of the input signals to the character signal generator 20 shown in FIG. 1. The heating of the printing elements 40 may also be controlled by controlling the secondary impedance load on the transformers 38 to provide a short circuiting impedance across the plurality of printing elements 40 or by saturating the transformer cores with direct current. In this method of operation, a pulse or steady A.C. electric current may be passed through the entire printing wire or bar 24. The printing elements 40 may also be short circuited by relays or other low impedance devices without the use of transformers. A plurality of terminals 42 is provided so that electrical connection may be made to the primary windings of the transformers 38.

FIGS. 5 and 6 show the parallel embodiment of the printing head. In this embodiment, a plurality of connector plates 44, composed of material similar to that described above, are separated by a plurality of layers of insulation 46. The connector plates 44 are disposed perpendicular to a solid common connector block 48 of the same material as the connector plates 44, which block is separated from the laminated structure of connector plates 44 by a layer of insulation 50. A plurality of wire or rod segments 52 extending between each connector plate 44 and the common connector block 48, serve as printing elements. In this embodiment, the heat sensitive tape is moved in a direction parallel to the wires or rods 52. External electrical connection is made to the connector block 48 by a lug 54 and is made to each of the connector plates 44 by connecting to an associated connection tab 56. The laminated structure of the connector plates 44 and the insulating layers 46 is assembled by means of a tightening nut 58 and bolt 60, fitting into a hole journalled through the laminated structure. The bolt 60, as has been described above, may be made hollow for the purpose of carrying a suitable coolant, if desired.

As in the series embodiment, the contact face of the parallel embodiment may be made curved rather than flat as shown in FIG. 5, the printing rods 52 may be recessed into the plates 44, and the gaps between plates 44 may be filled with insulation so as to present a smooth surface to the moving tape, as described above.

In FIG. 6, the electrical connections to the printing head are shown. A plurality of transformers 62 are shown each having one end of its secondary winding connected to the printing elements 64. Each of the opposite ends of the secondary windings is connected to the common connection block 48. The primary windings of the transformers 62 are each connected at one end to ground potential and at the other end to one of plurality of terminals 66 for further connection to the character signal generator 20. The parallel embodiment shown in FIGS. 5 and 6 is somewhat simpler electrically than the series embodiment shown in FIGS. 3 and 4 in that direct drive of the individual printing elements 64 is possible, eliminating the transformers 62. If desired, a plurality of auto-transformers may be substituted for the conven-

tional transformers 62. Direct drive may be accomplished by the discharge of capacitors through the printing elements 64, the capacitors being actuated by mechanical contacts, thyatrons or other solid state equivalents such as controlled junction rectifiers. Although direct drive is theoretically possible with the series embodiment, individual power supplies would be required for each heating element and such an arrangement would be costly and awkward.

In the series embodiment, it is evident that the heat sinks are disposed between adjacent elements forcing a minimum spacing between adjacent dots, however in the parallel embodiment, the heat sinks are not so disposed and it is possible to obtain prints with little or no spacing between adjacent dots, thereby increasing the overall contrast of the printing.

While the invention has been described with a certain degree of particularity, it is to be understood that the particularity shown has been by way of example and that numerous changes can be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A high-speed printing head comprising a plurality of thermally and electrically conducting plates separated from each other by insulative layers and forming a laminated structure, each of said plates being selectively adapted to receive electric current and to transmit said current therethrough, and a plurality of printing elements mounted on said plates and adapted to receive electric currents, said elements being electrically and thermally connected to said plates, each of said printing elements being relatively small with respect to said plates and further adapted to attain relatively high temperatures in response to said electric currents.

2. A high-speed printing head comprising a plurality of thermally and electrically conducting plates separated from each other by insulative layers and forming a laminated structure, each of said plates being selectively adapted to receive electric current and to transmit said current therethrough, and a printing bar disposed perpendicular to said plates and mounted on said plates, said bar comprising a plurality of adjacent portions, each portion constituting a printing element, each of said printing elements being thermally and electrically connected to said plates and further adapted to attain relatively high temperatures in response to said electric currents, each of said printing elements being relatively small with respect to said plates.

3. A high-speed printing head comprising a plurality of thermally and electrically conducting plates separated from each other by insulative layers and forming a laminated structure, each of said plates being selectively adapted to receive electric current and to transmit said current therethrough, a common connector block disposed perpendicular to said plates and separated from said plates by an insulative layer, said block being adapted to receive electric current and to transmit said current therethrough, and a plurality of printing elements adapted to receive electric currents, each of said printing elements being relatively small with respect to said plates and said block, and being electrically and thermally connected to one of said plates and to said block, each of said printing elements being further adapted to attain relatively high temperatures in response to said currents.

4. A high-speed printing device comprising a thermally sensitive medium adapted to produce local darkening thereon upon the application of heat thereto; a printing head adapted to contact said medium and responsive to electric currents for assuming relatively large changes in temperature in relatively short times, said printing

head comprising a plurality of thermally and electrically conducting plates separated from each other by insulative layers and forming a laminated structure, each of said plates being selectively adapted to receive electric current and to transmit said current therethrough, and a plurality of printing elements mounted on said plates and adapted to receive electric currents, said elements being electrically and thermally connected to said plates, each of said printing elements being relatively small with respect to said plates and further adapted to attain relatively high temperatures in response to said electric currents; a transport mechanism for providing movement of said medium with respect to said printing head; and input means for selectively supplying electric currents to said printing head.

5. A high-speed printing device comprising a thermally sensitive medium adapted to produce local darkening thereon upon the application of heat thereto; a printing head adapted to contact said medium and responsive to electric currents for assuming relatively large changes in temperature in relatively short times, said printing head comprising a plurality of thermally and electrically conducting plates separated from each other by insulative layers and forming a laminated structure, each of said plates being selectively adapted to receive electric current and to transmit said current therethrough, and a printing bar disposed perpendicular to said plates and mounted on said plates, said bar comprising a plurality of adjacent portions, each portion constituting a printing element, each of said printing elements being thermally and electrically connected to said plates and further adapted to attain relatively high temperatures in response to said electric currents, each of said printing elements being relatively small with respect to said plates; a transport mechanism for providing movement of said medium with respect to said printing head; and input means for selectively supplying electric currents to said printing head.

6. A high-speed printing device comprising a thermally sensitive medium adapted to produce local darkening thereon upon the application of heat thereto; a printing head adapted to contact said medium and responsive to electric currents for assuming relatively large changes in temperature in relatively short times, said printing head comprising a plurality of thermally and electrically conducting plates separated from each other by insulative layers and forming a laminated structure, each of said plates being selectively adapted to receive electric current and to transmit said current therethrough, a common connector block disposed perpendicular to said plates and separated from said plates by an insulative layer, said block being adapted to receive electric current and to transmit said current therethrough, and a plurality of printing elements adapted to receive electric currents, each of said printing elements being relatively small with respect to said plates and said block, and being electrically and thermally connected to one of said plates and to said block, each of said printing elements being further adapted to attain relatively high temperatures in response to said currents; a transport mechanism for providing movement of said medium with respect to said printing head; and input means for selectively supplying electric currents to said printing head.

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